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IN TWO SECTIONS

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EDITORIAL DEPARTMENT NOTE

Where several co-products or joint-products, or where one main product and several by-products are obtained from a single raw material, there is serious question whether really significant unit costs for final products can be determined. Where the selling prices of the final products tend to vary widely and not in unison, it may even be unwise to attempt to determine unit costs of products. These are some of the conclusions of the author of the article in this issue of the *Bulletin*, which we feel will be of interest to all members whether or not connected with the oil refinery industry.

The author of this article is Samuel K. Waters, all of whose business experience has been in the oil industry. Educated at the University of Pennsylvania, Mr. Waters spent the next ten years with the Atlantic Refining Co. of Philadelphia, the last seven years of which were in the capacity of Chief Refinery Accountant. For the past ten years he has been associated with the Crown-Central Petroleum Corp. at Houston in various capacities. He is now Treasurer and Controller of that company. Mr. Waters is a charter member of the Houston Chapter.

Articles published in the Bulletin present many different viewpoints. In publishing them the Association is not sponsoring the views expressed, but is endeavoring to provide for its members material which will be helpful and stimulating. Constructive comments are welcomed and will be published in the Forum Section of the *Bulletin*.

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SEPTEMBER 1, 1942

Crown Central Petroleum Co.
800 Amer. Bldg Balt. 2 Md.

OIL REFINERY ACCOUNTING

By Samuel K. Waters,

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A GREAT deal of accounting literature—both general and specialized—has been produced in the last twenty years, but that pertaining to the refining of crude petroleum has been meager to a point of sketchiness. On the other hand there has been a considerable amount of conversation on this subject. The reason for this lies in the fact that refinery accounting is not practiced on a definite basis, which is due principally to products manufactured being both co-products and by-products.

Processes Described

Before getting into the subject of oil refinery accounting, I am going to take a little of your time to briefly discuss what is meant by "oil refining." The leading processes, simply classified, which are chiefly utilized are: topping, cracking, reforming, lube manufacture, and catalytic processes for specialized products. Crude oil comes to the refinery a single homogeneous material, which when charged into topping stills is separated by the process of boiling or distillation into gases, gasoline, kerosene, fuel oils, lubricating oils, asphalt, coke and many other products and chemical compounds. This is accomplished by heating to successively higher degrees of temperature and the vapors of the various overhead light products are separated. Each of these constituent portions of the raw crude oil has a different boiling or vaporization point. The vapors are passed from the still to condensers where, by cooling, the vapors become liquid products. The products so secured may be either finished or unfinished, depending on the type or kind of distillation that produced it and the particular specifications. If unfinished, the product may be redistilled, washed, treated with chemicals, filtered, or subjected to some further special processing.

The other processes all utilize the application of heat and seek as their purpose a molecular rearrangement to produce the desired

products; cracking, reforming, polymerization, hydrogenation and catalytic reaction comprise this group, and they are generally found in a variety of combinations of methods and processes in any individual refinery.

The variety of refining methods, together with the increasing improved new processes in the science of petroleum refining, contribute to the difficulty of costing products.

Large Operating Units Make Costing Difficult

Approximately twenty-five years ago all refining was done in batch processes, or completely refining a given amount of crude oil to ultimate products before more raw crude oil was put into process. In addition, the number of units of equipment required for each operation was far more than the number of individual units required today. Thus materials in process were transferred through several individual units before they were finally classed as finished.

Today single operating units, heating the materials only once, or twice at the most, complete the refining to ultimate products. Thus, where it was once relatively simple to allocate costs of the several individual operating units of products processed, it has now become relatively difficult to make any sort of allocation where processing is accomplished in one complex combined single unit.

Refinery accounting other than the general books can be divided into three catagories, as follows:

1. Accounting control of inventory quantities
2. Distribution of refinery operating expenses to the operating units
3. Distribution of refinery operating costs to products produced

Accounting Control of Inventory Quantities

This problem is readily appreciated by specific examples. For instance, if 100,000 barrels of crude oil are received into a refinery tank and the price is $1.50 per barrel, this represents $150,000 worth of oil. Also if a ship's cargo of 100,000 barrels of gasoline is loaded in 20 hours or less and the value per barrel is $2.50, the value of the oil loaded is $250,000.

Interplant transfers of thousands of dollars worth of oil prod-

ucts are made each day in normal operations. Due to the enormous monetary value of raw and finished material passing through a plant, it has been found necessary to adequately account for the inventory. Accounting technique, aided by the sciences of accounting, engineering and physics, has provided adequate, accurate and timely control of inventory volume or quantity.

Allowances for Temperature, Basic Sediment and Water

Since oils received, oils in process, and finished oils are held in storage tanks, inventories range into the hundreds of thousands of barrels, and since a temperature variation of 25° in refinery tankage inventory on heavy products causes a one per cent variation in quantity, due allowance and correction must be made for these changes. Inventories will constantly increase and decrease even within a very short period of time. To establish a standard correction figure for a change in temperature, the industry has adopted 60° F. as the standard temperature for all products and all inventories are adjusted to quantity they would represent at that temperature. The method of temperature correction as presently used is covered by the Bureau of Standards Supplement to Circular No. C-410.

Also in computing the quantities, allowance must be made for the basic sediment and water, which is particularly found in the bottom portions of crude and residual products storage tanks. B.S.&W. settles out in a distinct bottom tank layer, since it is heavier than oil and is not soluble in oil. If B.S.&W. is stirred or agitated with oil, a certain amount remains in suspension in the oils until sufficient time has been given for settlement. B.S.&W. corrections or adjustments are applied to all tank gaugings and/or oil transfers made on the various tanks.

Each tank when first built or later remodeled is strapped or measured for capacity by a company engineer, or by a certified petroleum inspector. From the strapping data is prepared a gauge table showing how many gallons or barrels per 1/32" each individual tank will hold. Thus, to gauge a tank, a reading is taken on the feet and inches and fractions of inches of material within the tank. A thief or chalk line is used to determine the quantity of basic sediment and water at the bottom of the tank. A Centrifuge test is made to determine the amount of B.S.&W. that is

in suspension. Using the gauges reported of feet and inches, B.S.&W. and temperatures, the accounting department makes corrections as outlined above to secure true and standard inventory quantity amounts.

The gauging of a tank may be either by reading the dial on an automatic gauge or by a tape line operated by a "gauger"; however, accountants, as a general rule, insist on gauge line measurements, as gauging by hand is the most accurate. Meter measuring of liquid pumped from one point to another through a pipe line may also be used. They are used continuously by stillmen to gauge their operations, but the accounting department places very little reliability on them.

Accounting for Inventory Quantities

As an example of inventory control, suppose all crude oil comes to the refinery through pipe lines. Each tank into which the crude oil is to be pumped is gauged before the pumping begins and another gauge is taken after the pumping has been finished. The report of the two gaugings is signed by both the pipe line gauger and refinery gauger, and the information is usually entered on what is commonly known as a "run ticket." This run ticket comes to the office where the quantity is calculated by taking the quantity in the tank at the beginning and deducting it from the quantity finally in the tank. This net quantity is then adjusted for temperature and B.S.&W. in the methods described. The pumper in charge of the battery of tanks also enters on his pumping report the opening and closing gauges, temperature, B.S.&W., etc. The tank into which this crude oil was received now becomes responsible for a certain amount of oil. Tanks are gauged at least once a day, usually at 7 A.M. If there is a disagreement in the amounts, the accounting department notifies the refinery head, who immediately institutes an "oil hunt" to locate the error, shortage or leakage. In most cases an error has been made; but, there are times when large actual losses are found.

Accounting for Transfers

After the crude oil has been received into the refinery storage tanks it may be, and is, transferred to other storage tanks, charged to the various units for processing or moved about for other

reasons. Control and accountability for such transfers is secured by gauging before and after all transfers. There are usually blending or charging tanks and rundown tanks. The charging tanks and rundown tanks are usually smaller than the regular storage tanks. The charging tanks are on a sort of platform where the material comes to rest before being charged to the various operating units and is accurately gauged. The rundown tanks are the tanks into which the material actually comes to rest immediately after coming through the processing equipment. This is in order that accurate gauges may be obtained for yields and also for inspection. Allowing for a reasonable amount of processing loss, which has been determined by previous experience, and also by laboratory reports, the gaugings from the charge tanks and the rundown tanks should be the same, although the products will be materially different. As will be discussed later, these gauges, for the purpose of yields, are very important from a profit and loss standpoint.

Internal check on quantities is secured by having a report come to the office daily of not only the 7 o'clock gauges as previously mentioned, but also of all pumpings made during the previous 24 hours. These pumpings are calculated and the entire amount of oil in the plant is balanced by using the opening gauges of the previous day, plus receipts into the refinery, less shipments out of the refinery, less normal operating losses. This figure should agree with the quantity shown on the 7 o'clock inventory.

Usually periodic gauges are made by company auditors and by certified petroleum inspectors.

Distribution of Refinery Operating Expense to Operating Units

Broadly speaking there are direct and indirect operating expenses—the same as in practically any other manufacturing industry—and these costs are handled in a similar manner.

Direct charges are those which can be definitely allocated to the individual operating units. They are operating labor, material, fuel, maintenance, chemicals, depreciation, direct taxes, water, steam, direct insurance, etc. These represent approximately 65 per cent of the total cost. Thirty-five per cent of the total cost consists of indirect costs which must be allocated to the various operating units through some method of proration. These are plant management, office, shipping, storage, general taxes, general

insurance, laboratory or testing, etc. As a general rule, this cost is allocated on a "through-put" basis; but where there is both a lubricating oil plant and a gasoline plant this is hardly fair. Through-put of a gasoline plant is far greater than the through-put of a lubricating oil plant of the same cost. Further, the handling of lubricating oil at a refinery is generally more expensive than that of handling gasoline.

There are other methods of prorating overhead, based on the value of the equipment, the amount of heat used, and on total direct operating expenses.

Methods of distributing overhead are controversial, but have been arrived at by making studies in some instances. It is felt there is no exact way of prorating this indirect expense and any method is satisfactory as long as it meets the problem of the individual refiner.

Maintenance and Construction Overhead

In addition to the indirect expenses mentioned above, there is usually an engineering division, a construction and maintenance division, a storehouse division and a tool division. The cost of operating these departments is charged to maintenance or new construction work through an overhead basis. This overhead must be predetermined before the beginning of each period and never exactly absorbs the operating expense of these divisions. The overage or underage on these divisions must be distributed at the end of the period. This is sometimes done on the basis of the amount of work and sometimes by throwing the overage or underage into general overhead and prorating on a general basis.

Yields More Important Than Operating Costs

It should be noted that in oil refining the total operating costs fluctuate very little. Operating labor, maintenance, supplies, and depreciation (which is a very large cost), fluctuate practically not at all, unless an entire unit is taken out of operation. Fuel for a modern refinery is at no cost. The majority of fuel used is gas from refining operations which if not used, goes into the air and is wasted. This will change as science develops methods of utilizing this product. The important fluctuation in the cost of petroleum products is the yields of the products from a barrel of crude oil.

Exhibit 4, at the end of this article, shows the normal yields and normal operating expenses; it also shows increasing variable operating expenses of 25 per cent; decreasing gasoline yields of 2 per cent and increasing residual fuel yield of 2 per cent. In arriving at variable expenses, we have taken into consideration the variable expenses which fluctuate in theory and are giving them the "break."

This exhibit shows that the profit on a barrel of crude oil is affected equally by a 25 per cent increase in variable cost, or a 2 per cent decrease in yield. This is due to refinery operating expenses being less than 12½ per cent of the cost of the finished products.

In determining the replacement of equipment at enormous costs, running into millions of dollars, the savings in operating expenses is a very minor item. It is the better yields and better products that make it necessary to build this new equipment. In many cases by improving yields a million-dollar piece of equipment will pay for itself in from one to two years. It may even increase the overall refinery operating expenses and process the same quantity of raw material.

In addition to the accounting for money spent in a refinery for operation, it is necessary to account for maintenance, construction, storehouse, Social Security taxes, etc. These are similar to the problems all accountants have mastered and are not taken into consideration.

Distribution of Refinery Operating Costs to Products Produced

There is absolutely no doubt in my mind but that there is some disagreement with previous comments, but I am equally sure that there will be few disagreements on the next statement, that *cost accounting or distribution of exact cost to finished products is generally unsatisfactory, unsolved, and apparently impossible of complete solution.* The nature of the raw material, containing such a conglomeration and combination of products, has defeated any and all attempts to distribute just and correct portions of its cost to the finished products.

A major oil company executive in reply to a questionnaire of the Federal Government emphasizes this fact in saying:

> "We have no method of accurately computing the cost of each product manufactured from crude oil, chiefly due to two

facts: first, because it is impossible to assign each product its just proportion of the cost of the raw material, the largest single item of cost, and secondly, because the refining processes are continuous and there is such an interrelation between them as to make the allocation of the processing costs to individual products impossible without major arbitrary assumptions."

Another major oil company executive, replying to the same questionnaire, expressed the opinion of the whole industry when he said:

"It is a recognized principle in the oil industry that it is impossible to determine separately the costs applicable to a particular product manufactured. The costs of manufacturing are joint and inseparable and the products themselves are commingled and blended before, during and after the refining process. The reporting company's subsidiary refining companies do not even, in all cases, keep the elements of cost segregated by individual refineries. . . .

"The industry has not folded its hands in silent submission, however, for various methods of cost distribution—peculiarly good or indifferently mediocre—have been devised to meet a problem seemingly impossible of solution. Some of the methods appear to be unsuitable to the needs of any individual oil refinery; others appear possible of adaption to any refinery in general, while the remainder apparently are well suited to the peculiar needs of individual refineries only."

Most refineries do endeavor to cost individual products and there are several methods in use. Before we discuss these methods, it would be appreciated if you would look at Exhibits 1, 2 and 3.

Basic Data

Exhibit 1 shows two types of crude oil processed in the Gulf Coast area, and the quantity of products obtained from each one by making only gasoline and residual fuel and by making gasoline, kerosene, distillate fuel and residual fuel. It is generally thought

that crude oil of a like gravity should bring a like price. This is a fallacy. The price of crude oil depends on yields and vicinity of market.

Exhibit 2 shows the trend of prices of products at the Gulf Coast during the last four years, and it is hoped you will note that the rise and fall of prices of various products are in no way relevant. This is important.

Exhibit 3 shows the statistics which have been used in compiling the various exhibits. The figures have been taken from publications that are accessible to the entire industry.

Before going much further it may be well to state that yields from a barrel of crude oil, although usually shown on a percentage basis, in reality show the fraction of a barrel of finished products obtained from a barrel of crude oil. For example, if we show 52 per cent gasoline, this means there are 52/100 barrels of gasoline in a barrel of crude oil, or rather obtained from a barrel of crude oil.

A few of the methods of costing products are discussed below.

Joint Products Method—Exhibit 5

The joint products method is often referred to as the "weighted selling ratio method," "sales value method," "yield value," and "sales realization method." This method of determining cost involves determining the sales value of the products yielded, and prorating the refinery cost of a barrel of crude oil, plus operating expenses to the products yielded on a percentage basis. This method does not say that any products are by-products, but rather that all products are co-products.

By-Products Method—Exhibit 6

This method is probably used by the greatest number of refiners. It assumes that the reason for operating a refinery is to make gasoline, and all products except gasoline are by-products. There is doubt as to the validity of this thought, as most refiners definitely plan their operations to make a certain portion of other overhead products, such as kerosene, distillate fuel, solvents, etc. This method is very simple, as will be seen by reference to Exhibit 6. By arriving at the realization on by-products and deducting this

realization from cost of the raw material, plus operating expense, you have the value of the gasoline in the crude oil.

Replacement Value Method—Exhibits 7A and 7B

This method regards gasoline as the main product and fuel oil as its only by-product. The cost of co-products is estimated by determining what value these co-products would have if processed further into gasoline and fuel oil. Two exhibits are shown to bring out two different formulas, the difference being that the formulas are directly opposite.

Exhibit 7A indicates the cost of processing a barrel of crude to gasoline and fuel oil, taking the estimated yields of gasoline and fuel oil in kerosene and in distillate fuel oil, and considering gasoline and heavy fuel to be worth the same in all instances. The operating expense is deducted from this value as no operating expense was necessary, although considered when processing the crude. The answer is then the value of a barrel of kerosene or a barrel of distillate fuel oil.

Exhibit 7B is a method of arriving at the value of co-products by an algebraic formula, using the realization for heavy fuel oil, a by-product, as part of the basic formula. It is complicated, but used as a general rule by equipment manufacturers in figuring pay-outs on equipment sold.

The costs arrived at by both methods are practically the same and would probably be exactly the same if decimals were carried to 9 or 10 places.

This is also a by-product method, but arrives at the value of co-products, based on the price of crude oil rather than sales value of co-products and by-products. Yields of co-products on the replacement value method must be arrived at from laboratory tests, as it is very seldom that by-products are further refined for gasoline and fuel oil in themselves. It is much simpler and the yields are much better if they are blended with heavier stocks for further cracking.

Yields depend on the constituency of co-products. Yield of gasoline from a 38 gravity distillate fuel will probably be 3 or 4 per cent higher than the yield from a 33 gravity distillate fuel and both of these products meet the specifications as set for No. 2 distillate fuel oil.

Barrel-Gravity and Gravity-Heat Methods—Exhbit 8

Exhibit 8, Schedule 1, shows the formula for the barrel-gravity method. A few companies, recognizing the principle that product content is a governing factor in determining crude cost and that this principle should not be completely ignored in allocating the costs to production, have adopted a compromise to the joint products method. This method, referred to as the "barrel-gravity method," weights the barrels of products produced with the gravity of each individual product. The individual barrel-gravities so secured are expressed as a per cent of the total barrel-gravities, the total refinery operating costs then being allocated to the various products on the basis of this "barrel-gravity per cent."

This method is obviously quite simple and adaptable. It secures no accurate costs as there is no perfect correlation between the two weighting factors and actual cost. There is some small degree of correlation between gravity and commercial values of products; but, as a general rule, cracked or high octane gasoline shows a lower cost than straight run gasoline, and the former has a better sales value.

Schedule 2 of Exhibit 8 shows another formula, known as "gravity-heat unit" method. This distributes only the crude costs on the basis of gravity content of each product and distributes the refinery operating expenses on the basis of the best units applied in securing each product. Crude costs are distributed on the barrel-gravity method, as outlined above, and distribution of operating costs necessitates that a record or estimate be kept of the heat units applied to secure each product from the distillation process. The heat units for each process are expressed as a per cent of the total heat units applied and the refinery operating expense then distributed on the basis of these percentages. The individual crude and refinery operating expense distributions are added together to secure the total of each individual product.

This method appears to closely approach correct costing of the various refinery products; but, based on sales value, there is no sound basis for the assumption that the gravity of each of the many products manufactured bears a direct relation to the gravity of the raw material. This method was tried by one large oil company and experimented with by several more. As far as is now known, it is not being used.

Other Methods

Another method of approach is that of allocating costs purely on the basis of quantity, allocating an equal share of the total refinery costs to each product. The result is that a barrel of fuel oil costs exactly the same as a barrel of gasoline. This is a very simple procedure, but is definitely in error, as it is realized that all products do not have the same value even though produced from one base stock.

It will be noted that I have not touched upon the subject of valuing material in process. Practically all refiners value material in process according to products that will be derived after deducting operating expenses in order to finish.

In checking over the various methods referred to above, it will be realized that the question of allocating costs is a matter of opinion and that the basis used in various refineries is selected to meet this opinion. Some refiners contend that the manufacture of gasoline keeps the refinery in business and any value received for by-products is a gain. As previously pointed out, practically all refiners operate to make a quantity of co-products as demanded by consumers. There have been times when it was profitable to curtail the manufacture of gasoline and to manufacture more co-products.

Exhibit 9 shows profit or loss from processing the two crudes pictured on Exhibit 1 over a four-year period, on the maximum gasoline basis and on the maximum co-product basis. In 1937, 1938 and 1939, the most economical operation was to run for gasoline and heavy fuel; in 1940, it was advantageous to run for maximum co-products.

Profit Measured in Terms of Barrel of Crude Oil

From the above it is believed that a refinery should not attempt to determine the cost of individual products; rather, the accounting procedure can be of far greater value to the management where confined to a determination of the direct unit operating costs of the various processes, together with a tabulation of conditions and yields. It is further believed that the majority of cost methods, apparently and in reality, place too much emphasis on the net profit per barrel of individual products.

The vitally important item is the profit on a barrel of crude oil, which includes all the products. Furthermore, direct unit operating costs are readily usable by the refinery operating executives for control and reduction of refinery operating expenses and for measuring and comparing the efficiency of men and equipment. Having before it at all times unit operating costs, the management can determine the profit or loss that will result from the addition, deduction or abandonment of processes or equipment.

For instance, a new crude may be discovered which will yield a far different proportion of various products than any presently known crude. There is only one way of knowing whether to process this crude—knowing what products may be expected from each barrel processed, what it will cost to process the one barrel, what the products yielded can be expected to realize, and what ensuing profit and loss will result.

Needless to say, we are vitally concerned about making the largest profit or the least loss. A large oil company does not have as much choice in the selection of crude as does a small refinery—the normal kind—but from the economics available as to possible supply and demand of finished products during the ensuing period, it is the duty of the refinery accountant to point out to the management, prior to contracting for or purchasing crude oil, which crude oils will result in the most profit, and also the yields to be obtained from the crude oils to be processed.

A very grave danger in pricing individual products is that after they are manufactured and costed, there may be a severe drop in the market price of one product, and the psychological effect on the sales department of selling individual products at a loss may deter the sales and cause the products to be held in inventory, awaiting a rise in the market. During this period there is likely to be a further reduction in price. I have seen this happen. At the same time another product from the same barrel of crude may have had a rise in price. If individual products had not been priced, the company would have taken the profit on the products from a barrel of crude and the yearly statement would have shown much better results. Exhibit 10 shows how simple it is to arrive at the estimated profit per barrel of crude oil.

Inventory Valuation

My final remarks relate to a hitherto untouched subject, the valuation of refinery products in inventory. As has been mentioned before, the sales volume and sales prices of petroleum products in the United States are quite seasonal. Summer months are the "peak periods" for gasoline and the yearly low for co-products; quite the reverse is true for the winter season, when gasoline sales volume and prices fall to a yearly low, while co-product prices rise to a yearly high.

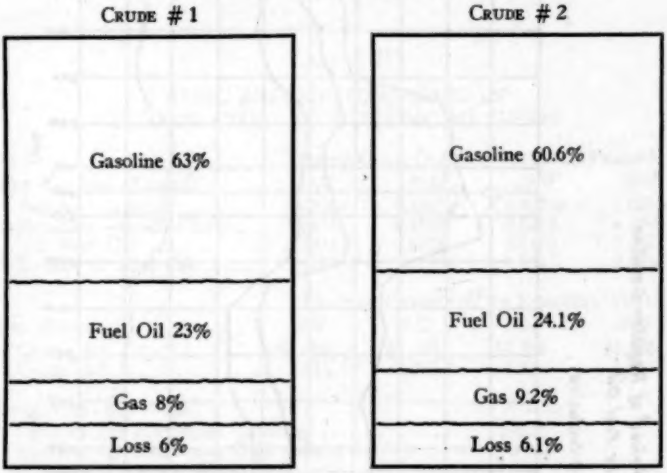
These various pronounced seasonal variations in sales have a very material effect on inventory valuation—both where costs are determined by valuing co-products and by-products at market price and where the lower of cost or market is applied. Unfortunately, most companies close on a calendar year, catching the prices at a seasonal extreme. This means that the supply and demand factor, dictating the market prices, will cause gasoline to be valued at an extremely low figure. Gasoline, when later sold in the summer months, will realize an undue profit; or, to be analytical, some of last year's profit is hidden in this year's inventory. Fuel oil sales and inventory will be just the reverse, overvalued inventories giving expression to last year's profit.

At first glance it appears that the extremes really offset each other and to some extent they may, but when you consider that the seasonal fluctuations are neither equal, proportionate, parallel nor relative, and that inventory quantities may show considerable fluctuation, there is very little offsetting.

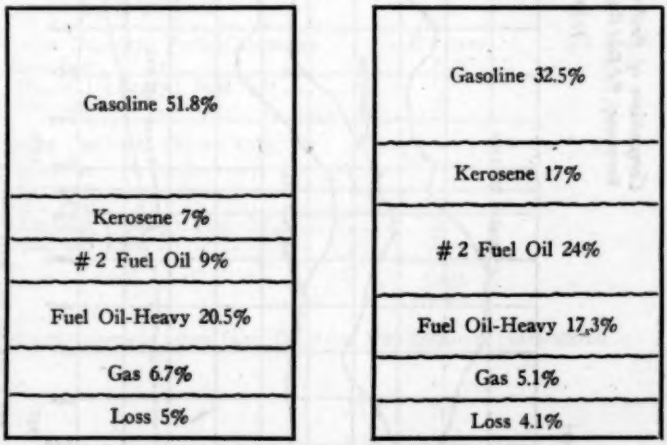
Should the inventory procedure apply the "last-in, first-out" rule, the major portion of the effect of seasonal price variation will be shown in the profit and loss statement, but in the final analysis, any inventory valuation or procedure ultimately has its effect on the profit and loss statement.

EXHIBIT 1

YIELD: RUNNING FOR MAXIMUM GASOLINE



YIELD: RUNNING FOR MAXIMUM BY-PRODUCTS

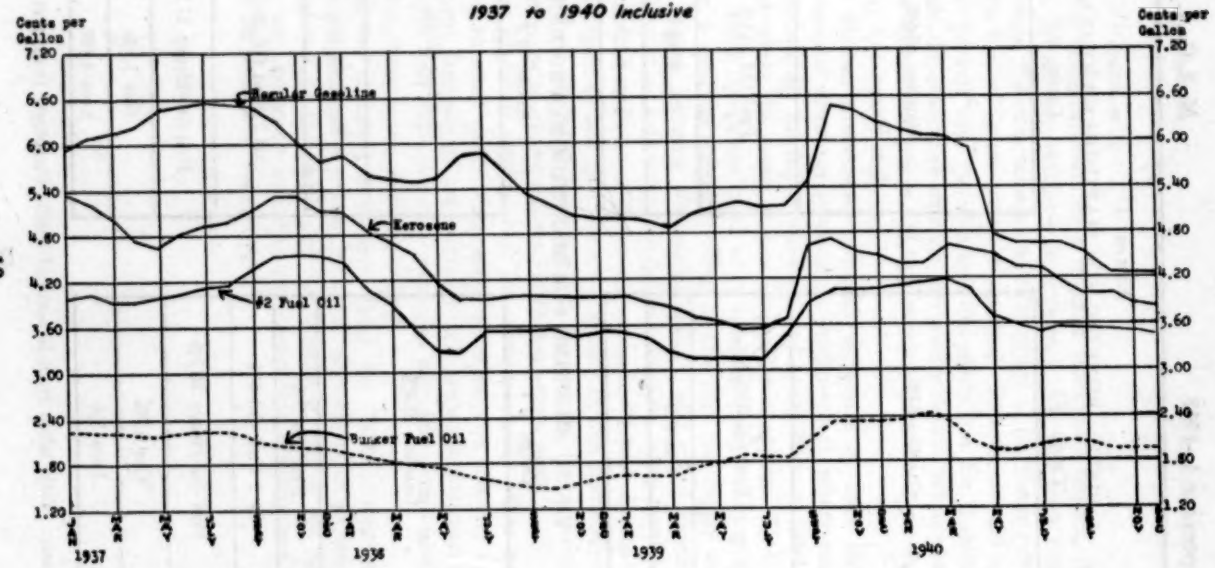


Source: Yield taken from Reports of Public Petroleum Inspectors.

EXHIBIT 2

Comparison of Posted Retail Prices of Regular Gasoline Kerosene, #2 Fuel Oil, & Bunker Fuel Oil*

1937 to 1940 Inclusive



* All prices are Gulf Coast Domestic

Source: Oil Price Handbook

EXHIBIT 3

BASIC ASSUMPTIONS USED IN ILLUSTRATING ACCOUNTING METHODS

PER GALLON (CENTS):	POSTED GULF COAST WHOLESALE PRICES*: 1937	1938	1939	1940
Regular Gasoline	6.2739¢	5.4585¢	5.4225¢	5.0051¢
Kerosene—41/43 White	5.0656	4.2826	4.0292	4.2495
#2 Fuel Oil	4.1864	3.6318	3.5370	3.7271
Bunker C Fuel Oil	2.1788	1.6795	1.9333	2.0938

PER BARREL:	PRICE OF CRUDE OIL AT REFINERY FOR: 1937	1938	1939	1940
Crude #1	$1.498	$1.470	$1.286	$1.286
Crude #2	1.415	1.355	1.13	1.13

OPERATING EXPENSES:	*Per Bbl.*
Running for Maximum Gasoline	$0.22
Running for Maximum By-Products	0.21
Cracking Expense—Variable	.05

Assumed yields are as shown on second chart below; all accounting method illustrations use 1937 Cost of Crude #1 and yields from Crude #1 running for maximum by-products.

YIELDS OBTAINED FROM CRACKING:	*Kerosene*	*#2 Fuel Oil*
Gasoline	75%	61%
Residual (Heavy) Fuel Oil	15	29
Gas and Loss	10	10

YIELDS OBTAINED FROM CRUDE:	
Gasoline	52%
Kerosene	7
#2 Fuel	9
Residual (Heavy) Fuel Oil	21
Gas and Loss	11
	100%

* Yearly averages taken from Oil Price Handbook for years shown.

Source: Oil Price Handbook

EXHIBIT 4

COMPARISON OF PROFITS ON OPERATIONS AT NORMAL, OPERATING EXPENSES INCREASED 10%, AND GASOLINE YIELD DECREASED 2%*

"NORMAL" OPERATIONS		*Per Barrel*
Cost of Crude Oil at Refinery		$1.4980
Operating Expenses:		
Variable	$ .08	
Fixed	.13	.21
Total Costs of Refining		$1.7080
Deduct Allocation to other products:		
Heavy (Residual) Fuel Oil, 9.66 Gals.		.2105
Cost of 26.46 Gals. Gasoline		$1.4975
Cost of 42 Gals. Gasoline		$2.3770
Posted Retail Sales Price (Average for 1937)		2.6350
Profit on Operations, Per Barrel Gasoline		$.2580
VARIABLE		
Operating Expenses Increased 25%		
Cost of Crude at Refinery		$1.4980
Operating Expenses:		
Variable (125% of $ .08)	$ .10	
Fixed	.13	.23
Total Cost of Refining		$1.7280
Deduct allocation to other products:		
Heavy (Residual) Fuel Oil, 9.66 Gals.		.2105
Cost of 26.46 Gallons Gasoline		$1.5175
Cost of 42 Gallons Gasoline		$2.4087
Posted Retail Sales Price		2.6350
Profit on Operations, Per Barrel Gasoline		$0.2263
Gasoline Yield Decreased 2%		
Total Cost of Refining, as above (Normal)		$1.7080
Deduct allocation to other products:		
Heavy (Residual) Fuel Oil, 10.19 Gallons		.2220
Cost of 25.93 Gallons Gasoline		$1.4860
Cost of 42 Gallons Gasoline		$2.4069
Posted Retail Price		2.6350
Profit on Operations, per barrel gasoline		$ .2281

* Running Crude #1 at 1937 prices for maximum yield gasoline.

EXHIBIT 5

PRODUCT COSTS ALLOCATED BY JOINT PRODUCTS METHOD

YIELD:	*Per Cent Barrel Yielded*	*Realization Value—B*	*Sales Value*	*Allocated Cost—A*
Gasoline	52%	$2.6350	$1.3702	$1.2518
Kerosene	7	2.1276	.1489	.1361
#2 Fuel Oil	9	1.7583	.1582	.1445
Heavy Fuel Oil	21	0.9151	.1922	.1756
Gas and Loss	11	-0-	-0-	-0-
Total	100%		$1.8695	$1.7080

	UNIT COSTS *Per Gallon*	*Per Barrel*
Gasoline	$ .0573	$2.4073
Kerosene	.0463	1.9443
#2 Fuel Oil	.0382	1.6056
Heavy Fuel Oil	.0199	.8362

B—Prices Based on 1937 Prices—Exhibit No. 3.

A—Multiply yield (per cent) by sales value of product—This gives sales value of quantity of each product per barrel. These values added will give selling price of all products from barrel of crude. This divided into cost of crude plus operating expense:

($1.7080 ÷ $1.86950 = 91.36132%) will give ratio of sales value to refinery cost. This ratio is then multiplied in individual product sales value to get individual product allocated cost, i.e.:

$$52\% \times \$2.6350 = \$1.3702 \times 91.36132\% = \$1.2518$$

This product allocated cost then divided by percentage of individual products to get the allocated cost per barrel, i.e.:

$$\$1.2518 \div 52 = \$2.4073$$

EXHIBIT 6

PRODUCT COSTS ALLOCATED ON BY-PRODUCTS (REALIZATION) METHOD

	Per Cent Barrel	*Realization Value—A*	*Refinery Value*	
Cost of Crude at Refinery.....	100%			$1.4980
Operating Expenses				.21
Total Operating Costs.....				$1.7080
Deduct credit for By-Products:				
Kerosene	7%	$2.1276	$ .1489	
#2 Fuel Oil	9	1.7583	.1582	
Heavy Fuel Oil	21	0.9151	.1922	
Loss	11	-0-	-0-	.4993
Cost of Gasoline	52			$1.2087
Cost of Gasoline Per Barrel...				$2.3244

	UNIT COSTS *Per Gallon*	*Per Barrel*
Gasoline	$ .0553	$2.3244
Kerosene	.0506	2.1276
#2 Fuel Oil	.0419	1.7583
Heavy Fuel Oil	.0218	.9151

A—Multiply yield of by-products, or co-products, (Per cent) by sales value of product. These values are then added, and the total deducted from cost of crude plus operating expense to arrive at the amount allocated to the barrels of gasoline produced.

Priced based on 1937 Prices—Exhibit 3.

EXHIBIT 7A

PRODUCT COSTS ALLOCATED BY BY-PRODUCTS (REPLACEMENT VALUE) METHOD

BASIC COST OF GASOLINE	*Barrels*	*Value Per Barrel*	*Total Per Barrel*
Cost of 100 Barrels Crude #1	100	$1.4980	$1.4980
Add: Refinery Operating Expenses, running for maximum gasoline			.2200
Total Costs	100		$1.7180
Deduct: Credit for 23 Barrels Heavy Fuel Oil at Market	23	.9151	.2105
Gas and Loss	14	....	....
Net Cost, 63 Barrels Gasoline	63	$2.3929	$1.5075

VALUE OF BY-PRODUCTS	*Per Cent of One Barrel*	*Value Per Barrel*	*Total*
Kerosene:			
Produces—Gasoline	75%	$2.3929	$1.7947
—Residual Fuel Oil	15	.9151	.1373
—Gas and Loss	10	....	....
Total	100%		$1.9320
Deduct—Finishing Costs			.2200
Replacement Value per Barrel			$1.7120
#2 Fuel Oil			
Produces—Gasoline	61%	$2.3929	$1.4597
—Residual Fuel Oil	29	.9151	.2654
—Gas and Loss	10	....	....
Total	100%		$1.7251
Deduct—Finishing Costs			.2200
Replacement Value per Barrel			$1.5051

ACTUAL COST OF GASOLINE			
Cost of One Barrel Crude, plus Refining Expenses	100%	$1.7080	$1.7080
Yields:			
Kerosene	7%	$1.7120	$ .1198
#2 Fuel Oil	9	1.5051	.1355
Heavy Fuel Oil	21	.9151	.1922
Gas and Loss	11	....	....
Total Value of By-Products	48%		$ .4475
Value of Gasoline Produced	52%	$2.424	$1.2605

PRODUCT COST VALUE—PER GALLON	
Gasoline	$ .05771
Kerosene	.04076
Distillate Fuel	.03584
Heavy Fuel	.02179

EXHIBIT 7B

PRODUCT COSTS ALLOCATED BY BY-PRODUCTS (REPLACEMENT VALUE) METHOD

Determination of values of kerosene and distillate (#2 Fuel Oil) fuel oil on crude replacement basis:

Cost of gasoline from cracking kerosene or distillate fuel oil and crude must be the same.

K = Replacement Value of Kerosene
D = Replacement Value of Distillate Fuel
C = Delivered Cost of Crude ($1.4980 per bbl.)
F = Residual Fuel Oil Realization ($.9151 per barrel)

$(K - .15F)/.75 = (C - .23F)/.63$
$K = (.75/.63)\ (C - .23F)/.15F$
$= 1.1905C - .1238F$, or
$K = 1.1905\ (1.4980) - .1238\ (.9151) = \$1.6702$
Cracking Expense .0500
Cost of Kerosene Per Barrel 1.7202

$(D - .29F)/.61 = (C - .23F)/.63$
$D = (.61/.63)\ (C - 23F)/.29$
$D = .9683C - (-.0673)$
$D = .9683\ (-.1498) - (-.0673)\ (.9151)$ $1.5121
Cracking Expense .0500
Cost of Distillate Fuel Per Barrel $1.5621

	Per Cent of Barrel	*Value Per Barrel*	*Total*
Cost of Crude at Refinery			$1.4980
Operating Expenses			.2100
			$1.7080
YIELDS:			
Kerosene	7%	$1.7202	$ .1204
#2 Fuel	9	1.5621	.1406
Heavy Fuel Oil	21	.9151	.1922
Gas and Loss	11	....	....
Total Value By-Products	48%	....	$ .4532
Value of Gasoline Produced	52%	$2.413	$1.2548

Product Cost Value—Per Gallon

Gasoline	$ .05745
Kerosene	.04096
Distillate Fuel	.03719
Heavy Fuel	.02179

EXHIBIT 8

Schedule 1

BARREL-GRAVITY METHOD OF COSTING PRODUCTS

The following costs are assumed:

Crude Oil at Refinery	$1.4980
Refinery Operating Costs	.2100
	$1.7080

YIELDS	*Yield Per Cent*	x	*Gravity*	=	*Barrel Gravity Factor*	*Barrel Gravity Per Cent*	*Allocated Cost*
Gasoline	52%	x	52°	=	2704	74%	$1.2639
Kerosene	16	x	33°	=	528	15	.2562
Heavy Fuel Oil	21	x	19°	=	399	11	.1879
Gas and Loss	11	x	-0-	=	-0-	-0-	-0-
Totals	100%	x			3631	100%	$1.7080

Per barrel costs of various products may be found by dividing yield per cents into allocated costs and multiplying by 100. Thus, gasoline costs per barrel equal (1.2639 ÷ .52) × 100, or $2.4306.

Schedule 2

GRAVITY-HEAT UNIT METHOD OF COSTING PRODUCTS

YIELDS	*Barrel Gravity Per Cent*	*Allocated Crude Cost*	*Heat Units Per Cent*	*Allocated Refinery Operating Expense*	*Total Costs*
Gasoline	74%	$1.1085	38%	$0.0798	$1.1883
Kerosene & Gas Oil	15	.2247	9	0.0189	.2436
Heavy Fuel Oil	11	.1648	53	0.1113	.2761
Gas and Loss	-0-	-0-	-0-	-0-	-0-
Totals	100%	$1.4980	100%	$0.2100	$1.7080

The "barrel-gravity per cent" is found as in the barrel-gravity method. Costs per barrel as outlined in that latter method.

EXHIBIT 9

REALIZATION ON CRUDE #1 AND CRUDE #2 ON GASOLINE AND ON BY-PRODUCT OPERATION

	1937	*1938*	*1939*	*1940*
Operating Profit or Loss*:				
Running for maximum gasoline:				
Crude #1	$ .1526	$ .0835*	$ .1156	$ .0206
Crude #2	.1823	.0157*	.2259	.1357
Running for maximum By-Products:				
Crude #1	.1516	.0846*	.1024	.0390
Crude #2	.1734	.0260*	.1849	.1744

* Red

EXHIBIT 10

REFINED PRODUCTS FROM ONE BARREL OF CRUDE OIL	*Gallons*	*Sale Price Per Gallon*	*Sale Value*
Gasoline	21.76	$ .062739	$1.3652
Kerosene	2.94	.050656	.1489
#2 Fuel Oil	3.78	.041864	.1582
Heavy Fuel Oil	8.61	.021788	.1876
Gas and Loss	4.91	-0-	
	42.00		$1.8599
Less: Refinery Operating Cost per Barrel			.21
Net Value at Refinery			$1.6499
Cost of Crude Oil Per Barrel			1.4980
Profit Per Barrel			$ .1519

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